



## **Board of Forestry Literature Review**

### **Preliminary Exchange Function Themes**

The following outlines some of the preliminary results from our literature review. These are subject to considerable refinement, and are intended as a preview of things to come.

### ***Biotic/Nutrient Themes***

- Plankton-dominated to algal-dominated shifts food base
- Timing of litter – fast litter v slow litter
- Alder is good for nutrients (but not so for LWD)
- Patchy heterogeneity benefits aquatic conditions locally, with limited downstream benefits (drift limited to ~ 100 m)
- Fish productivity benefits by increased light (at risk to temperature)
  - Scale dependent (1-3 order)
  - Regional variability in benefit likely
- Inferences about scale of patches (both temporal and spatial)
- Strategic use of patches at biological hotspots, fire-risk. Also mosaic shifts?
  - Alluvial gravels (substrate)
  - Tree Species risks (sudden oak death, climate changes, etc)
  - Gradient knickpoints
  - Tributary junctions
  - Hyporheic exchange sites?? (inferred by geomorphology)
- Buffer width inferences are limited by presented literature
  - Group selection-like corridors
  - Non-conventional configuration
  - Silvicultural factors
  - What core objectives
- Hyporheic zone – HYDROLOGY??
  - Beginning to understand effects
  - Important redox relationships
  - Important macrobiotic habitat
  - Limited manipulation by forestry
  - Wood-driven sediment wedges
  - Not clear that there is a benefit in managing specifically for hyporheic zones
- Where the bugs are v. what the fish can utilize
  - Openings can improve food conversion efficiency for fish
  - Bioenergetics models (e.g. Sullivan et al) indicates that entire regime is more important

## **Heat Themes**

- Only paper on regional variability (Lewis et al)
- Density & basal area has poor correlation to canopy closure
- Microclimate and stream temperatures are related by several corresponding variables (e.g. ) but stream temperatures not likely influenced by microclimate
- Lewis et al (2000) is THE report for CA
- Carefully consider response to Q2 – specifically with regard to management effects (e.g. q 2a & 2b doesn't directly address forest mgmt).

## **Wood Themes**

- Mass wasting skews curves away from FEMAT curves
- Bank erosion & windthrow skews FEMAT effectiveness curves toward the stream
- Redwood chronic mortality is very low – requires disturbance to deliver (burn, flood, landslide)
- DF Landscape may require strategies focused on MW as delivery mechanism.
- Mortality rates change over time. Silviculture can be used to affect mortality (and growth) rates for the benefit of desired conditions
- Is wood a critical factor in Sierra channels (look at physiographic variability)
  - Elevation
  - Geology
- Is wood important structurally in small channels?
  - Wood for delivery to fish channels (df, flood)
    - Low
    - May have local effects
  - Disturbance limitations for sediment integrity
- Utility of uniform, continuous buffers may not be required
  - Discontinuous, heterogeneous buffers may offer value to the landscape
- Watershed recruitment potential should be considered at a watershed scale
  - Expand beyond McDade et al type curves to consider the cumulative watershed-scale effects
    - Ameliorating effects include no harvest zones, landslides, natural variability, harvest-related increases in growth and/or density, etc.

## **Sediment**

- Just reviewed riparian functions – was not presented with any of the vast literature on hollow failure processes
  - We see 0-order is covered by mass wasting & not riparian
  - Thus we are only addressing surface erosion & bank erosion processes
- Deal with the increased scour potential associated with Interception effects
- Roughness elements are dynamics, and include small branches, microtopography, understory veg, etc.



***Board of Forestry Literature Review***  
**Preliminary Synthesis Outline**

**Synthesis Goals**

We think it is helpful to outline the goals of our synthesis approach. The SWC Team has identified these as follows:

- Demonstrate dynamics among and between exchange functions
- Identify a small set of variables of interest that can be used to capture scales of variability
- Summarize important gaps
- Summarize how this aggregation of reviewed literature affects our understanding of forest management guidelines

**SYNTHESIS OUTLINE**

***1. Summary of Findings***

This section will also include reporting and discussion of the consistency and applicability of the reviewed literature toward addressing key questions

**1.1 Biotic/Nutrients**

**1.2 Wood**

**1.3 Sediment**

**1.4 Heat**

**1.5 Water**

## **2. Summary of Key Information Gaps**

## **3. Dynamics Among Exchange Functions**

### **3.1 Common Functional Dependencies???**

[note: we are of mixed opinion here – this type of synthesis has been commonly done, but results are not always very satisfactory]

### **3.2 Spatial & Temporal Heterogeneity & Variability**

#### **3.2.1 Role of Disturbance**

The Context of Forest Management In Terms Of Natural Disturbance Processes

Management Affects On Natural Disturbance Regimes

#### **3.2.2 Landscape-scale Shifts in Driving Functions – the Role of Watershed Context**

Scale & Distribution of Processes over the Landscape

Geographic Configurations

Geomorphic Configurations

Availability of Dynamic Corresponding Factors

Process-Oriented Approaches

## **4. Opportunities for Management Variables**

This section will discuss a range of possible management variables that can be used to represent key sources of variability and/or integration. For example,

- Watershed Context (network location)
- Flow/Morphology (gradient/confinement)
- Elevation/Latitude (Regional Climate)
- Groundwater/Geology
- Species Mix/Canopy/Structure

*[these are subject to revision – they are preliminary]*

## **5. Inferences for Policy**

This section will outline some key considerations for riparian management that the Board might consider in its deliberations for setting riparian management policies. We will outline some general approaches for dealing with some of the findings that can address some of the dynamics and key findings of our review.

We stress that we will NOT recommend prescriptions or preferred direction, but will concentrate on describing some general implications for a selected set of objective approaches.

For example, the SWC Team would comment on the implications derived from the literature that might be considered in developing solutions for a range of potential policy approaches as follows (these are examples, subject to review and revision).

**Protect Functions** – this approach might seek only to minimize impacts from forest harvest practices near riparian zones. This has been the historic approach used by many forestry agencies over the last 15+ years.

**Correct Undesired States** – this approach might allow treatments in riparian zones to correct for undesired conditions (for example, the Hardwood Conversion approach used in Washington State)

**Enhancement** – this approach might support treatments in riparian zones that are directed to correct for historical management practices, and moving these systems more towards some desired condition based on an understanding of riparian ecosystem processes

**Watershed Mosaic** – this approach, borrowed from landscape ecology, would seek to develop a landscape over time that includes a wide array of conditional states

For each of these approaches, the SWC Team would objectively summarize the state of the science as it applies to each approach by focusing on limitations in knowledge, uncertainties, ranges of variability, findings from the literature, etc. We envision that this discussion would be supported by a matrix that would objectively compare the information derived from the literature to each approach.

## **WATER RIPARIAN EXCHANGE KEY QUESTION RESPONSES**

Riparian zones in forested watersheds play a number of important hydrologic and water quality roles, whose importance far exceeds their relative surface area. These roles include:

- **Channel Structure & Morphology.** Vegetation patterns strongly influence how flows create both the primary channel morphology, as well as secondary preferential flow pathways in both surface and subsurface environments (Thorne et al, 1997; Swanson et al 1998; McDonnell 2003).
- **Runoff generation.** During precipitation, riparian zones quickly become saturated, and are the first parts of a watershed to begin contributing runoff (McDonnell 2003). They account for most on the runoff on the rising limb of the hydrograph, whereas hillslopes contribute more on the falling limb. Three primary sources of groundwater exist (riparian, hollow and hillslope) and these sources are non-linear and distinct both chemically and isotopically (McDonnell 2003).
- **Moderating flood peaks.** The high resistance to flow (friction) of riparian vegetation and woody debris slows water velocities, reduces peak discharge and affect flood synchronicity (Tabacchi et al, 2000; Nilsson & Svedmark, 2002)
- **Nutrient Exchange.** Hydrologic conditions significantly affect the supply, availability and distribution of nutrients throughout the channel network (Tabacchi et al 2000).
- **Hyporheic flow.** Flow through the hyporheic zone, which overlaps with the riparian zone, is important in regulation of stream water quality (Tabacchi et al 2000). Redox reactions in the hyporheic zone are important for immobilizing, transforming and releasing forms of nitrogen and phosphorus.
- **Transpiration.** Vegetation in the riparian zone, especially hardwoods, seasonally transpires more water per unit area than upslope vegetation, and may have a strong influence on summer low flow and riparian microclimate (air temperature and relative humidity).

These points provide a context for considering the following questions:

**1. How do forest management activities or disturbances in or near riparian zones/floodplains, and adjacent to small headwater first and second-order channels affect flow pathway and streamflow generation?**

The information available in the selected literature suggests that riparian zones strongly influence stream-generation functions in small headwater channels, and that disturbance processes substantially affect the condition and evolution of riparian areas. Disturbances that affect riparian zones include forest management activities, flooding, mass wasting, fire, wind, infestation, disease, and competition mortality. The processes by which these disturbances affect headwater streams are highly variable, complex, dynamic and spatially distributed. Some of the effects from these disturbance processes are essential for developing rich habitat conditions, both locally and in downstream reaches, which increases the benefits to aquatic species. Other disturbance effects have the potential to degrade conditions. Generally speaking, smaller, frequent and varied disturbances increase the heterogeneity of flow pathways, leading to an environment that is more resilient, diverse and rich. By contrast, disturbances that are large and infrequent tend to lead to more widespread changes that have larger physical impacts.

**A) Have forest management activities in riparian zones for higher order channels with floodplains and adjacent to small headwater first and second order channels been shown to alter water transfer to stream channels, affecting near-stream and flood prone area functions (e.g., source area contributions to stormflow, bank instability, lateral and vertical channel migration, flow obstruction or diversion of flow)?**

Yes, forest management activities in these areas can affect stream functions. The distribution of such effects likely vary with topography and geology. The mechanism for these effects is the removal of trees, and the associated loss of canopy interception and evapotranspiration, and as such, we should anticipate that harvest effects are similar to those found in natural disturbance processes like fire (Dwire et al 2006). The general scale of effects appears to be largest from clearcutting in smaller watersheds (Lewis et al

2001). The literature we reviewed primarily discussed the effects from timber harvest on peak flow and water yields, and only inferred impacts to stream channels and flood-prone riparian areas. *[NOTE to TAC: we may apply results from other assigned Exchange Function literature to this question in subsequent drafts].*

Disturbances from large floods are highly heterogeneous and support a complex mosaic of riparian and aquatic habitats (Swanson et al 1998). In many cases, the flood disturbance signature will reflect the riparian conditions at the time of the flood. Large floods can recruit, entrain and mobilize woody debris, reorganize channel morphology, and transfer sediment from hillslopes to riparian zones through mass wasting. It's unlikely that the magnitude of large floods is significantly influenced by forest management activities, although the limited number of observations may be a factor (Moore and Wondzell 2005).

Forest management activities in a watershed (road building and tree removal) have been shown to increase peak runoff, with the effect diminishing as the frequency of the event decreases (Ziemer and Lisle 1998). The effect is generally greater in the fall, when the difference in soil moisture between cut and uncut areas is greatest (Moore and Wondzell, 2005; Beschta et al., 2000). Insert table showing results. At Caspar Creek, the average percentage increase in peak flow for a 100% clearcut area was 27 percent for the 2-yr event (Ziemer, 1998 as reported in Lewis et al, 2001). In snow-dominated landscapes in Colorado, peak flow increases ranged from none detected to 87% and total water yield increased by up to 80% in small catchments using various treatments (Moore and Wondzell, 2005). At E. St. Louis Creek in Colorado, the increase was 25 percent for events with recurrence intervals (RI) of 2-5 yrs. In terms of sediment transport (and possibly channel erosion) these would be significant increases (Moore and Wondzell, 2005).

The paired watershed studies on which these conclusions were based, however, address watershed-wide impacts, not just management activities in the riparian zone. In the literature that we have reviewed, there is only one study dealing with hydrologic impacts of activities confined to the riparian zone. A study on

impacts of fuel reduction in a “Stream Environment Zone” (SEZ)<sup>1</sup> of the Tahoe basin looked at impacts on the saturated hydraulic conductivity (Ksat) of soils in an area thinned (of lodgepole pine) with a low-ground-pressure CTL forwarder/harvester. The average Ksat across the area, including areas outside of the harvester tracks, was reduced by over 50 percent, even though the loamy coarse sand soils were dry at the time (Norman, et al., 2008). The reduction in Ksat was attributed to horizontal spreading of applied pressure (due to equipment vibration) through layered soils. Because the SEZ was relatively flat, and the initial Ksat was high (5.5 in/hr) the reduction in Ksat in this instance would be unlikely to cause surface erosion. In an Australian Eucalyptus forest, Croke et al (1999) documented reductions in Ksat of approximately 50% following riparian logging, although the method of logging is not clear. In other circumstances, such a reduction could increase surface erosion and modify flow pathways, since riparian areas are known to be vulnerable to soil compaction and physical disturbance due to areas of high moisture and low soil strength (Dwire et al., 2006).

**B) Have forest management activities in riparian zones for higher order channels with floodplains and adjacent to small headwater first and second order channels been shown to result in changes in tree canopy/volume that significantly affects evapotranspiration and/or interception, with resultant changes in water yield, peak flows, low flows, etc.?**

It is not clear if there are significantly different effects from canopy removal in riparian zones. Interception and canopy evaporation typically reduces the total amount of rainfall reaching the ground surface by about 20% over the season (Lewis et al, 2001). The literature reports that the amount of change in water yield, peak flows and base flow associated with timber harvest is directly related to the amount of tree canopy removed, regardless of where in the watershed those trees are removed. However, our

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<sup>1</sup> SEZs in the Tahoe Basin are defined as biological communities that owe their characteristics to the presence of surface water or a seasonally high ground-water table.

understanding of fundamental hydrologic processes suggests that tree removal in riparian zones would impart different effects than upslope tree removal. The expected hydrologic response to riparian tree removal is complex. To our knowledge, specific effects have not been directly studied and the net effects are subject to some debate.

### *Peak Flows*

The direct peak flow response from reduction of tree canopies in riparian zones has not been directly studied. In theory, since rainfall runoff in riparian zones is more likely to fall onto saturated soils, and riparian zones are generally closer to the stream, removal of riparian canopy might cause an almost immediate increase in peak flow, or at least a steeper rate of rise in the hydrograph for small rain events. However, the largest increases in peak flows observed in clearcut watersheds usually follow the storms with the driest antecedent conditions (when riparian zones are likely unsaturated (Ziemer and Lisle, 1998; Beschta et al, 2000; Lewis et al, 2001), suggesting that the relationship between riparian canopy removal and peak flows is more complex.

Large precipitation events (or events with an already saturated canopy) are unlikely to be affected by riparian canopy removal (Beschta et al, 2000). To our knowledge specific studies of the response from riparian areas alone are not available, in part because statistically valid measurement of responses from riparian timber harvest alone are extremely difficult to obtain.

The effect of reduced interception might be most significant in steep, zero-order basins, where hollows are filled with colluvium and at risk for slope failure even when unsaturated. An intact canopy can moderate the intensity of short bursts of rainfall reaching the soil surface, and its removal may thus increase the potential rate of water input to the soil and the likelihood of slope failure. Such processes reflect highly complex soil physics relationships (e.g. Torres et al 1998; McDonnell, 2003) that are not well understood, and were not a focus of this literature review.

Water Yield & Summer Baseflow

Water yield increases following timber harvest have been well documented (Ziemer and Lisle, 1998; Lewis et al, 2001; Moore and Wondzell, 2005) and are attributed to reduced evapotranspiration. Generally, the reduction in transpiration resulting from tree removal makes more water available for flow during the summer, and in some circumstances, this can be beneficial to aquatic organisms. However, where harvest of conifers in the riparian zone results in conversion to deciduous species, summer low flow may be reduced (Moore & Wondzell, 2005).

The literature related to water yield and base flows do not distinguish between removal of trees from riparian areas and other areas of the watershed. But total water consumption varies dramatically by species, even in similar soil moisture and climate conditions (Tabacchi et al, 2000).

The increase in summer low flow that results from reduced evapotranspiration may be substantial from even modest treatments (Table X), but generally decline to an insignificant level after a few years (Moore and Wondzell, 2005; Ziemer and Lisle, 1998).

**TABLE X) SUMMARY OF REPORTED SUMMER YIELD RESPONSE<sup>2</sup>**

Location	Watershed	Watershed Size (ha)	Treatment Area	Treatment Type	Increase in Summer Yield
Coastal CA	SF Casper Ck	484	67%	Selection	120%
	NF Casper Ck	473	12%	Clearcut	150%
	NF Casper Ck	473	42%	Clearcut	200%
Oregon Cascades					<b>Annual Yield</b>
	HJ Andrews 6	13	100%	Clearcut	30%
	HJ Andrews 7	15.4	100%	Clearcut	22%
	Coyote Creek	69.2	100%	Shelterwood	8%
	Coyote Creek	68.4	30%	Patchcut	14%

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<sup>2</sup> Data compiled from Ziemer & Lisle (1998); Moore and Wondzell (2005)

Location	Watershed	Watershed Size (ha)	Treatment Area	Treatment Type	Increase in Summer Yield
Oregon Coast Range	Coyote Creek	49.8	100%	Clearcut	43%
	Needle Branch	70.8	82%	Clearcut	26%
	Deer Creek	30.4	25%	Patchcut	insignificant
					<b>Annual or Seasonal Yield</b>
Colorado	Wagon Wheel Gap	81	100%	Clearcut	15%
Rockies	Fool Creek	289	40%	Patchcut	45%
North-Central Idaho	Horse Creek 12	84	33%	Patchcut	80%
	Horse Creek 12	62	27%	Patchcut	79%
	Horse Creek 12	28	21%	Patchcut	51%
	Horse Creek 12	86	29%	Patchcut	52%

**C) Can forest management activities in riparian areas alter water yield, peak flows or low flows sufficiently to affect channel morphology or the aquatic ecology of headwater streams?**

While large floods and mass wasting are the primary mechanism for creating the structural foundation for diverse aquatic habitat mosaics within the headwater channel network (Swanson et al 1998; Nilsson & Svedmark 2002), the indirect hydrologic effects of riparian management can influence both channel morphology and aquatic ecology in headwater streams. These relative impacts from such effects are mixed, and depend on the watershed and regional context, including such key factors as site gradient, valley confinement, regional geology, elevation, dominant riparian tree species, location within the watershed, and riparian stand condition.

*Channel Morphology*

Pioneer vegetation can encroach upon sand and gravel bars during low flows, which can affect flow hydraulics, thus influencing both local channel morphology and aquatic habitats (Tabacchi et al 2000). Water yield and summer baseflow conditions can affect the distribution of riparian species that become established in riparian

zones, especially in the years immediately following disturbances (Dwire et al. ; Nilsson and Svedmark, 2002). Homogenous riparian stands generally offer lower habitat quality than more heterogenous stands formed from disturbance-initiated vegetative dynamics (Tabacchi et al 2000). Riparian stand complexity provides a higher stem density that increases turbulence during peak flows, which results in more complex channel conditions, more habitat diversity, and greater resilience. These patterns are important in both lateral and downstream directions.

The indirect effect of increased peak flows specifically from riparian timber harvest on headwater channels has not been directly studied, due to the extreme difficulty of isolating the effects of timber harvest on hillslope and riparian zone contributions to the runoff hydrograph. For example, Moore and Wondzell (2005) outline at least 18 different papers that infer the importance of “forest harvest activities” on channel morphology. Most of these inferences are with regard to wood supply and sedimentation, presumably from harvest activities and upslope erosion.

Lewis et al (2001) identified significant increases in suspended sediment yield from treated headwater watersheds in Casper Creek, and demonstrated that these increases are strongly correlated to increased volume of streamflow during storms after logging. Median suspended sediment yields generated from individual storms in partial cut watersheds increased by 64% over pre-harvest yields, and 107% in clearcut watersheds. Annual suspended sediment yields increased by 73% and 212% respectively. Sources of sediment were identified to include roads, riparian windthrow, and erosion from unbuffered streams (particularly in those watersheds that were broadcast burned after harvest). However, increased peak flows were implicated in affecting observed bank erosion, headcutting, and soil pipe enlargements.

Even modest increases in peak flows of the type observed in the literature (e.g. Lewis et al 2001, Moore and Wondzell, 2005, etc) can be important in some watershed contexts. When such peak flow increases occur in steep channels with erodible substrates, they can potentially increase sediment production from headwater streams. Similarly, increased flow duration in erodible landscapes can also affect stream sediment production. Steep headwaters are particularly sensitive to increased shear stress during modest flows.

Such effects can potentially be ameliorated by increased roughness provided by woody debris, steps, and riparian vegetation.

#### *Aquatic Ecology*

Riparian tree growth appears to benefit by increased baseflows (Disalvo and Hart, 2002), which may explain the more robust vegetative conditions observed in riparian zones. Lateral soil moisture increases can also affect zonation of riparian vegetation (Nilsson and Svedmark, 2002).

Aquatic species generally recover quickly from even severe flood disturbances, usually in as few as 1-3 years (Swanson et al 1998).

During extended dry periods, portions of headwaters channels become dry when the transpiration water losses from riparian vegetative exceeds streamflow and hillslope contributions to the riparian zone (Moore and Wondzell, 2005). Increases in summer water yields from upslope timber harvest may decrease the length of dry reaches, effectively extending the perennial channel network (Liquori, 2003), which affect the species distribution and richness of macroinvertebrates (Price et al, 2003).

[NOTE TO TAC: We expect additional information to address this question to come from the pending Biotic & Nutrient Exchange Function review]

#### **D) Can forest management activities alter water quantity in riparian zones for higher order channels with floodplains sufficiently to affect overflow/side channels that serve as refugia for fish during floods?**

The answer to this question is “probably not”, for two reasons. First, as noted above, the effect of timber harvest activities on peak flow is greatest for small storms and those in the fall. An increase in discharge for small storms could increase the frequency of flow in overflow/side channels, but that would unlikely affect the availability of the side channels as refugia. Second, the streams with overflow channels and defined floodplains are likely to be 4<sup>th</sup> or 5<sup>th</sup> order channels draining a relatively large area. Lewis et al. (2001) showed that complete clearcutting of a catchment can cause an increase of 27 percent in the peak flow magnitude of the 2-yr event in relatively small watersheds (e.g. ~1200 acres), however the

potential for peak flow effects decreases significantly in larger basins (Thomas & Megahan 1998), largely due to asynchronization of flow timing from contributing basins (Ziemer and Lisle, 1998).

As described above, while increase in summer flows following upslope timber harvest is well documented, it is unclear if the volume of increased summer flows from treated areas can be sufficient to significantly increase habitat availability (e.g. river stage) for summer rearing.

Also, as noted earlier, deciduous riparian vegetation can have higher summer transpiration than conifer species, and thus the distribution of riparian vegetation could influence any net flow benefit from upslope treatments.

Heavy equipment operation in the riparian zone could modify flow in side channels, but equipment is often excluded from the riparian zone by existing forest practice regulations.

**E) Do forest management activities in riparian zones for higher order channels with floodplains and adjacent to small headwater first and second order channels significantly affect hyporheic exchange flows?**

It appears likely that forest management activities can significantly affect hyporheic exchange flows, although not necessarily in response to hydrology effects from riparian management. The primary factors controlling hyporheic exchange appears to be the channel and valley shape, porosity of the streambed, and wood loading (USFS-PSW, 2004). The science on this topic appears to be somewhat immature.

One significant forest management factor is the input of fine sediment to the stream enough that the open pore space in gravel becomes clogged and inflow at point-bars and step-pools is reduced (Hancock, 2002). A second is by modifications that affect the recruitment of woody debris.

Hydrologically speaking, Wondzell and Swanson (1999) showed that extremely large floods, like the 1996 flood in the H. J. Andrews Experimental Forest, radically altered the structure of the hyporheic zone, changing flow-paths and residence time. A flood of

that magnitude is unlikely to be affected by timber harvest activities (Thomas & Megahan, 1998; Beschta et al, 2000).

Litter mats from deciduous trees can retard hyporheic exchange by seasonally limiting inflows, even as they increase nutrient availability to the aquatic community through litter (Tabacchi et al 2000).

While transpiration rates vary significantly by species (Tabacchi et al 2000), a mixed hardwood stand transpires water from soils at rates that vary from less than 1 foot over a summer season (Wulschleger, Hanson and Todd, 2001) to as much as 4 feet in extreme arid environments. On the conservative site, compacted soils might have a porosity of 20-30%, suggesting that typical riparian transpiration can lower the water table surface elevation by 2 to 5 feet in mixed hardwood stands over the course of an entire summer season, or as much as 12-20 feet in more arid environments. If one assumes that hyporheic exchange is at least partly influenced by water table elevations, it would follow that riparian conditions could influence hyporheic flows. However, it is not clear if removal of riparian vegetation increases or decreases hyporheic exchange, as no direct studies are known to exist.

*Insert appropriate statement(s) about expected trend of nutrient cycling from Biotic & Nutrient literature review.*

Hyporheic flows can also affect riparian vegetation, although the interactions between riparian communities and hyporheic conditions are not well understood (National Research Council, 2002). Harner and Stanford (2003) found that cottonwood (*Populus trichocarpa*) growth in a gaining reach was twice that of a losing reach, and that nitrogen was 16% higher relative to carbon in the gaining reach. Hinkle et al (2001) observed hyporheic exchange fluxes of 5-10% of the streamflow at reach-scales. McDonnell et al (1998) identified higher dissolved organic carbon delivery from hillslopes when riparian groundwater levels were higher.

## 2. What bearing do the findings of the reviewed articles have on riparian zone buffer strip delineation (area influencing water transfer/exchange function) or characteristics (cover, plant species and structure, etc.)?

It appears appropriate here to make a clear distinction between a riparian zone and a riparian buffer. Here, we use the term “*riparian zone*” to describe the area of hydrologic influence adjacent to the stream, and note that this zone is highly dynamic both in space and time. We use the term “*riparian buffer*” to describe a management zone that is typically defined by specified criteria, and which are typically static in space and time. We also note that the structure, distribution and operational guidelines in riparian buffers may be more important than the delineation of the buffer.

The reviewed literature did not specifically discuss the delineation of the hydrologically-influenced riparian zone. Dunne (1978) originally described spatially dynamic expansion of riparian saturation in response to storms and watershed conditions that probably remains valid today. Basically, there are primarily four dimensions that are important when considering the delineation of hydrologically-influenced riparian zones:

1. **Lateral** – the lateral dimension describes the width of the zone that is influenced by hydrologic functions. The primary variables that control this dimension include gradient, confinement and hydraulic conductivity (which is a function of soil type).
2. **Longitudinal** – the longitudinal dimension describes the upstream extent of the channel network that influences hydrologic functions. The primary variables that control this dimension include total precipitation, runoff mechanism (snowmelt v. rainfall), drainage density, gradient, confinement and hydraulic conductivity.
3. **Temporal** – the temporal dimension describes the amount of time that the riparian zone is influenced by hydrologic functions. Zones of influence can range from hours (during storms) to years (e.g. the perennial stream network). The primary variables that control this dimension include the upslope stand characteristics, as well as those variables that describe the longitudinal dimension.

Although the other exchange functions (nutrients, wood, heat and sediment) will offer additional factors affecting management of the riparian buffer, water functions (based in the reviewed literature) suggest

several important considerations with regard to characteristics of the buffer:

- **Uncompacted Soils** – soils in riparian zones can be vulnerable to soil compaction due high soil moisture and low soil strength (Dewire et al, 2006). Even dry soils of a riparian zone can loose hydraulic conductivity from heavy equipment operation (Norman, et al, 2008).
- **Canopy Retention** - Since rainfall on the riparian zone generates a rapid hydrograph response (Mc Donnell et al, 1998), it is reasonable to expect that complete canopy removal from the zone might have a disproportionate effect on the rising limb of the stormflow hydrograph. While some canopy removal may be appropriate for meeting other desired functions, it is not clear how much canopy is required to maintain functions. However, some reasonable guidelines may be developed by using applying hydrologic calculations using known relationships and/or models.
- **Heterogeneity** – greater heterogeneity in the species, density, age-classes and distribution of riparian vegetation appears to increase the quality of aquatic habitats (Nilsson and Svedmark, 2002; Price et al, 2003; Tabacci et al 2006).
- **Disturbance Risk** – riparian management (or lack thereof) can significantly affect the conditions and characteristics that influence other disturbance processes including fire and infestation risks (Dewire et al, 2006), vegetative succession (Nilsson and Svedmark, 2002), or landslide risk (Ziemer and Lisle, 1998).

### **3. Are there regional differences in the effects of forest management activities or disturbances in or near the riparian area/zone for the water transfer riparian function?**

Yes, there are regional differences, although the reviewed literature does not highlight them, since most of the studies are restricted to either Casper Creek (coastal Mendocino County) or other regions outside the state.

Flow conditions impose a "signature" that affects ecological and geomorphic functions and processes, and thus regional variation in five

key variables are important; runoff timing, frequency, duration, rate of change, and magnitude (Nilsson & Svedmark 2002). While not specifically addressed by the reviewed literature, it is appropriate to recognize that these 5 key variables are most directly influenced by:

**Regional Geology** – which affects the signature of infiltration and hillslope storage. For example, large sedimentary systems (e.g. coastal regions) typically experience much higher rates of hillslope storage than granitic terrains (e.g. Sierras).

**Topography** – affects the spatial distribution of stream channels and therefore the travel distance between the hillslope and channel. Elevation influences the form of precipitation (e.g. rain or snow) as well as the density of precipitation (e.g. orographic effects).

**Dominant Runoff Mechanisms** – rainfall runoff typically results in rapid hydrograph responses with limited canopy interception and variable source-area runoff mechanisms. Snowmelt typically produces higher canopy interception, accumulated seasonal storage and prolonged runoff periods. Areas prone to rain-on-snow events experience both types of runoff signatures, in addition to more frequent, large-magnitude and often highly erosive peak flows events.

For example, the Klamath-Siskiyou region and the Modoc-Shasta plateau region present an interesting contrast in hydrogeology and geomorphology, and their effects on runoff generation. In the former, slopes are steep, drainage density is high, and the rainfall-runoff response is rapid. There is a high degree of connectivity between the riparian zones of first-order streams, and the downstream reaches of larger streams. In the latter, slopes and drainage densities are low, and bedrock fractures and other subsurface openings convey much of the precipitation from soil to rivers. The degree of connectivity between first-order tributaries and larger streams is relatively low. Such contrasts can be drawn for many of the geographic regions of California.

## **Additional References**

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# *Sound Watershed Consulting*

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## **General Note on Literature Citations:**

The SWC Team anticipates the need to cite papers in our responses to Key Questions that extend beyond the literature review list. Such citations reference knowledge available to the SWC Team that is relevant to our discussion, but does not necessarily form the basis for our responses. As such, we see three types of literature that will be cited in our report

- 1) **TAC-Assigned Literature** – these articles will be included in Appendix G and will be the primary basis for our responses to Key Questions and Synthesis
- 2) **SWC Recommended Literature** – these articles will also be included in Appendix G and will be the primary basis for our responses to Key Questions and Synthesis
- 3) **Generally Known Literature** – these articles are already known to the SWC Team, and are used to support our discussion in the Key Questions and Synthesis sections. These articles will be cited in SWC deliverables, but will not be compiled in Appendix G.

## **SWC Recommended Additional Literature**

This list reflects revisions to the list provided with the Primer Review memo. It is more focused on those papers most likely to benefit responses to the Key Questions.

### **WATER**

Norman, S., T. Loupe, and J. Keely. 2008. Heavenly Creek SEZ Demonstration Project 2007 Soil Monitoring Report. USDA Forest Service Lake Tahoe Basin Management Unit. 58pp

### **SEDIMENT**

Allen, R. and W. MacNeill. 2004. Population-level responses to sediment during early life in brook trout J. N. Am. Benthol. Soc. 23(1):140–150.

White, J. and B. Harvey. 2007. Winter feeding success of stream trout under different streamflow and turbidity conditions. Transactions of the American Fisheries Society 136:1187–1192.

### **WOOD**

Martin, D. J. and R. A. Grotefendt. 2001. Buffer zones and LWD supply. Project Report prepared for Alaska Forest Association and Alaska Department of Environmental Conservation. Community Water Quality Grant No: NP-01-12.

Mitchell, S. and J. Rodney. 2001. Windthrow Assessment and Management in British Columbia  
Proceedings of the Windthrow Researchers Workshop, January 31-February 1, 2001, University  
of British Columbia, Vancouver BC, Canada.

### HEAT

Ebersole, J., P. Winington Jr., J. Baker, M. Cairns, M. Church, B. Hansen, B. Miller, H. LaVigne, J.  
Compton, and S. Leibowitz. 2006. Juvenile coho salmon growth and survival acrossstream  
network seasonal habitats. Transactions of the American Fisheries Society 135:1681–1697.

Neiltz, M., E. MacIsaac, and R. Peterman. 2007. A Science-Based Approach for Identifying  
Temperature-Sensitive Streams for Rainbow Trout. North American Journal of Fisheries  
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### BIOTIC & NUTRIENTS

Frady, C., S. Johnson, and J. Li. 2007. Stream macroinvertebrate community responses as legacies of  
forest harvest at the H.J. Andrews Experimental Forest, Oregon. Forest Science 53(2):281–293.

Frazey, S. and M. Wilzbach. 2007. The Relationship Between Productivities of Salmonids and Forest  
Stands in Northern California Watersheds Western Journal of Applied Forestry 22(2): 73-80.

Hayes, S., M. Bond, C. Hanson, E. Freud, J. Smith, E. Anderson, A. Ammann, and B. MacFarlane.  
2008. Steelhead growth in a small central California watershed: upstream and estuarine rearing  
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Moldenke, A. and C. Ver Linden. 2007. Effects of Clearcutting and riparian buffers on the yield of  
adult aquatic macroinvertebrates from headwater streams. Forest Science 53(2):308 –319.

Romero, N., R. Gresswell, and J. Li. 2005. Changing patterns in coastal cutthroat trout  
(*Oncorhynchus clarki clarki*) diet and prey in a gradient of deciduous canopies. Can. J. Fish.  
Aquat. Sci. 62: 1797–1807.

Wipfli, M.S. 1997. Terrestrial invertebrates as salmonid prey and nitrogen sources in streams:  
contrasting old-growth and young-growth riparian forests in southeastern Alaska, U.S.A. Can. J.  
Fish. Aquat. Sci. 54: 1259–1269.

White, J. and B. Harvey. 2007. Winter feeding success of stream trout under different streamflow  
and turbidity conditions. Transactions of the American Fisheries Society 136:1187–1192.

### DISTURBANCE

*These disturbance papers will a) help to provide a context for management activities, and b) be used to infer potential  
responses from management activities where specific studies do not exist (e.g. most literature either has buffers or does  
not have buffers, thus looking to disturbance literature will help evaluate partial disturbances in riparian areas and will  
help to understand dynamics between exchange functions).*

Everett, R., Schellhaas, R., Ohlson, P., Spurbeck, D., and Keenum, D. (2003) Continuity in fire  
disturbance between riparian and adjacent sideslope Douglas-fir forests. Forest Ecology and  
Management v. 175: 31-47

Dwire, K.A., and Kauffman, J.B. (2003) Fire and riparian ecosystems in landscapes of the western

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- Rieman, B., Lee, D., Burns, D., Gresswell, R., Young, M., Stowell, S., Rinne, J. and Howell, P. (2003) Status of native fishes in the western United States and issues for fire and fuels management. Forest Ecology and Management 178:197-211